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SPATIAL ANALYSIS OF SUSTAINABLE LIVELIHOOD ENTERPRISES OF UGANDA COTTON PRODUCTION

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ABSTRACT

Because the conditions for agricultural development vary considerably across space, we need to develop methods that allow us to take such variability into account when evaluating development strategies for particular crops or farming systems. This paper addresses spatially varying characteristics in an evaluation of the potential economic benefits of three cotton development strategies for Uganda: area expansion, productivity improvement, and domestic consumption increase. We begin with a historical review of cotton production in Uganda. We then described the major challenges and opportunities for Ugandan cotton production, including farm-level production constraints. Household-level production data from the 2000 Uganda National Household Survey (UNHS) are used to estimate the current spatial distribution of cotton production (called the cotton production area, or CPA), based on the association of household cotton production with ranges in mapped variables (altitude, length of growing period, and population density), district cotton production statistics and expert knowledge of local production patterns. Cotton development domains (CDDs) are then defined by agroclimatic suitability, market/ginnery access, and inclusion in the CPA. We use the UNHS data to evaluate the importance of cotton as a livelihood enterprise and its role in rural livelihood strategies. Key ecosystems and protected areas are considered in conjunction with the CDDs in defining feasible areas for expansion of production. Finally, the Dynamic Research Evaluation for Management (DREAM) model is used to estimate benefits that accrue from the three development strategies considered.

KEYWORDS: cotton, DREAM, productivity, spatial analysis, development strategy, development domains, Uganda, cash crops, export agriculture

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SPATIAL ANALYSIS OF SUSTAINABLE LIVELIHOOD ENTERPRISES OF UGANDA COTTON PRODUCTION

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1. INTRODUCTION

Cotton was introduced into Uganda in the 1900s by the contemporary British colonial government. Because of its excellent agroecological conditions, cotton produced in Uganda has a high-grade fiber of medium-staple (Serunjogi et al. 2001). This "bright white" cotton has a sustained international market. Although cotton is produced widely in Uganda, most production is concentrated in the Northern and Eastern regions. In 2000 there were approximately 300,000 to 400,000 cotton producers in Uganda (Gordon and Goodland 2000), who produced a total of 110,000 bales of lint cotton (1 bale = 185 kg). This is less than 60kg lint cotton per producer. Cotton in Uganda is produced mainly by smallholders; a recent survey found an average farm size of 3.2 hectares for cotton producers (Walusimbi 2002). While not universal, cotton production is widespread: in recent years cotton contributed to the incomes of an estimated 10 percent of the country's population, equivalent to about 2.5 million rural people in eastern, northern and western Uganda (COMPETE 2002). Because of this widespread role in household incomes, cotton is seen as having high potential for helping to reduce poverty in rural areas (ibid.; CDO 2001; Lunkbaek 2002).

Cotton was Uganda's major export crop until the 1950s, when it was surpassed by coffee. Cotton production prospered in the 1960s and early 1970s. It produced about 86 thousand metric tons (about 465 thousand bales) annually during this period, contributing roughly 40 percent of Uganda's foreign exchange earnings for this time period. Due to political and economic turmoil in the 1970s and 1980s, cotton production declined radically, hitting an all-time low of 11,000 bales in 1988. The annual growth rates for production, area and yield from 1971-81 are pronouncedly negative: –28 percent, -16 percent and –14 percent (Table 1.1). The cotton plantation area declined about 2.6 percent per year from 1981-94 while production picked up slightly, about 1.4 percent per year, mainly due to the gain from cotton yield. In 1994, the cotton market was liberalized with the implementation of Cotton Sub-sector Development Program (CSDP). This resulted in a rapid area expansion of cotton, about 16 percent annually from 1994–2000. However yields declined about 5.8 percent annually during this period. Overall, Uganda suffered a dramatic decline in both cotton production and area during the last four decades while its cotton yields have changed little. As a comparison, the world total for cotton area has shown little change; production increases have mainly derived from gains in yields(Table 1.1). The growth rates of export quantity and export values more or less follow similar trends with overall production in Uganda, which is unsurprising since over 90 percent of Uganda cotton is exported. Notably, Uganda has increased its exports by about 10 percent per year since the cotton market liberalization of 1994 while exports in the rest of world have declined about 4 percent annually. The different growth rates between export quantity and export values reflect the declining world cotton price in recent years.

Table 1.1—Annual growth rates of Uganda and world cotton

Country	Item	1961-71	1971-81	1981-94	1994-2000	1961-2000
				(%)		
	Production	4.58	-27.62	1.37	9.88	-6.10
Uganda	Area	1.66	-15.53	-2.58	16.40	-6.24
	Yield	2.87	-14.31	4.05	-5.57	0.15
	Production	2.30	1.23	1.34	-0.46	1.67
World	Area	0.65	-0.12	-0.21	-0.43	-0.01
	Yield	1.64	1.35	1.55	-0.03	1.68
Uganda	Export Quantity	3.22	-33.92	5.86	11.10	-8.36
	Export Value	2.42	-26.25	0.78	9.68	-6.23
World	Export Quantity	0.95	0.86	2.63	-4.13	1.16
	Export Value	1.27	10.03	1.30	-8.41	4.11

Source: FAOSTAT(2003)

FARM-LEVEL CONSTRAINTS FACING UGANDA COTTON

Despite promotion by the Ugandan government, the World Bank, the International Fund for Agricultural Development (IFAD), and other organizations, annual cotton production has dwindled by around 100,000 bales since 1994. Current production is less than one-fourth of Uganda's historical peak. Some studies have attempted to identify causes of the currently stagnant production situation. Major constraints on the level of production include: low productivity deriving from on-farm technologies such as hand hoe cultivation; limited availability of key inputs (e.g., fertilizer, seed and pesticides); insufficient research and extension services; limited access to credit for small farmers; and low producer prices (COMPETE 2002; CDO 2002; Walusimbi 2002; AGSEC 1999). Another major production constraint for smallholders is low profitability compared with other prevalent crops such as beans, maize, cassava, millet, sorghum, sesame and soybeans (AGSEC 1999; Walusimbi 2002). Table 1.2 compares the profitability of major smallholder crops in Uganda, based on household survey from 2000.

Table 1.2--Relative profitability of cotton and competing crops

Crop	Gross Margin (Shs/Ha)	Returns to family labour (Shs/Md)
Cotton	47,602	1,192
Beans	86, 466	977
Maize	46,831	2,934
Cassava	185,354	968
Millet	120,111	200
Sorghum	14,394	258

Source: IFPRI Household Survey 2000; Walushimbi 2002.
Note: Here profitability is measured by Gross Margin and Returns to Family Labor in studies done by ASPEC (1999 2001). They are defined as:
Gross Margin (Ush/ha) = Gross Value of Output – (Total Material Inputs Costs + Hired Labor Costs)
Returns to Family Labor (Ush/md) = Gross Margin/ Family Labor
While Gross Margin is defined by the planted area of the crop, Returns to Family Labor is normally measured in person-days (aka "man days" or "md"). Six hours of work is considered to be a person-day for adult workers and 3 hours for children between the age of 12 and 16.

Table 1.2 shows the profitability for cotton, beans, maize, cassava, millet, sorghum in 2000. As we can see, the gross margin of cotton is low compared to that of prevalent crop alternatives. In a survey in Mbale district in 2001, Lundbaek (2002) found that 57 percent of interviewed cotton farmers incur negative gross net revenue when the cost of family labor was accounted for. There are a few reasons why farmers continue to grow cotton even with such a low gross margin or even negative net revenue. First, cotton is increasingly becoming a more certain source of cash than its competing food crops. While food crops face large price variations due to change of demand and supply, the income from cotton is relatively certain due to well-defined and increasingly competitive market after the cotton market liberalization in 1994. Second, cotton cash payment comes at a convenient time when where are many cash expenditures at the time of the year (Christmas, school fees, taxes etc). Third, in integrated smallholder farming systems, cotton is a good land opening crop. Cotton growing leaves the soil fairly clean of weeds, which benefits the next crop. Finally, in some areas there may simply be no viable cash crop alternatives except cotton (Walusimbi 2002).

WORLD MARKET OUTLOOK

Since over 90 percent of Ugandan cotton is for export, the work cotton market is vital to Uganda cotton farmers. Prior to the market reform in 1994, the world cotton price was on the rise. The Cotlook A Index price[1] hit a record high in 1994 at 94.4 US cents/lb. After 1994, the price fell, hitting a low of 44 US cents in 2001. Since 2002, the A Index price has shown some recovery. According to International Cotton Advisory Committee (ICAC), the A Index price averaged 53.0 US cents/lb in 2002, and is expect to be around 57 US cents over

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[1] The Cotlook A Index price is an average of the five lowest quotes of cotton for delivery to Northern European ports. It has been recognized as the prime source of benchmark prices on cotton since 1967 and is currently the most quoted measure of world price.

the 2003/04 season. The dismal price in recent years has resulted in huge stocks in major cotton producing countries such as China, India, Pakistan, and United States. Therefore, the price recovery is expected to be slow and gradual (ICAC 2002; USDA 2002). On the other hand, there has been less price fluctuation in cotton prices since the world cotton supply and demand achieved some degree of equilibrium in 1997 (USDA 2002; USDA 2003). This relatively stable world market presents less volatility to small farmers in Uganda (relative to what happened in the 1990s).

OPPORTUNITIES AND CHALLENGES FOR UGANDA COTTON

Low world cotton prices have not helped efforts to revive Uganda's cotton production over the last few years. However, in a stabilized world market, Uganda has some good opportunities to revive its cotton sector. First, agroclimatic conditions in Uganda favor cotton production. As a result of these conditions, Uganda is able to produce a high quality, long-staple cotton which has a stable international demand. Second, currently low levels of productivity leave much room for improvement. This is borne out by comparisons with cotton productivity in agroecologically-similar neighboring countries (Gibbon 1998). Third, the African Growth Opportunities Act (AGOA) offers an average 17.5 percent duty advantage to sub-Saharan African exporters of apparel to the U.S., relative to non-African suppliers. Under the substantial incentives from this Act, some Indian and Chinese garment factories have started to set up operations in Uganda. This will not only increase the domestic demand for cotton in Uganda but also have additional income effects through increased industrial employment. In a recent study (Gibbon 2003), it was found that there is a significant level of response to AGOA in Africa, in particular in the garment manufactures targeted to US market. Given the challenges and opportunities for Uganda cotton sector, there might be three types of strategies to sustain or increase cotton producer and export earnings: (1) Area expansion. Increase production of cotton simply through expansion of the cultivated area (2) Increase domestic consumption of cotton by opening new textile factories (2) Increase cotton labor/land productivity. The productivity improvement could be achieved by introducing new inputs and technologies such as improved varieties, fertilizers, integrated pest management (IPM), animal traction.

As pointed out above, cotton is a smallholder production enterprise[2] in Uganda with the potential to play an important role in the livelihoods of rural people. Cotton income is the major cash income for many small farmers. In this paper, we applied a spatially-explicit strategic planning framework for sustainable land use (following Bolwig *et al*. 2002) to design development strategies for cotton production in Uganda. The framework features explicit treatment of livelihood strategies, technological changes, markets, and trade in an attempt to assess the local and aggregate effects of livelihood choices and environmental policies on a range of welfare outcomes. The framework consists of three major phases: the first phase assesses the status of human well-being and the environment, and identifies rural development constraints. The second defines and evaluates alternative rural development pathways (Pender et al. 2001) based on identified feasible intervention opportunities. The third phase assesses the potential environmental and human welfare consequences of different development scenarios. This approach is operationalized in a such way heterogeneity and fragmentation in the spatial distribution of production systems, which is typical of smallholder agriculture in sub-Saharan Africa in general and Ugandan cotton production in particular.

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[2] Livelihood refers to the specific economic or livelihood activities undertaken by rural households. Livelihood strategy refers to households' longer-term plans for successful livelihood (Pender et al. 2001). Livelihood enterprise is one activity, such as cotton production or brick making, of rural livelihood strategy.

The paper is organized as follows. First, we characterize the current cotton production zones and cotton-based livelihoods. We then examine the potential opportunities for cotton intensification and/or expansion, based upon the biophysical suitability of land for cotton production, access to ginneries and markets, key ecosystems and protected areas. This analysis results in mapped Cotton Development Domains (CDDs). Third, we simulate the welfare impact of different cotton development strategies and the consequences for cotton livelihoods, using the Dynamic Research Evaluation for Management (DREAM) model (Wood *et al*. 2000b). Finally, conclusions and policy implications are drawn from these analyses.

2. CHARACTERIZATION OF EXISTING COTTON PRODUCTION

The first step of the spatial-explicit development framework is to assess the current status of cotton production and the environment (Bolwig *et al*. 2002). In this section, we use a cartographic model to estimate the spatial distribution of existing production. In addition, we map key ecosystem and protected areas in Uganda, which would be considered when designing further cotton production expansion/intensification.

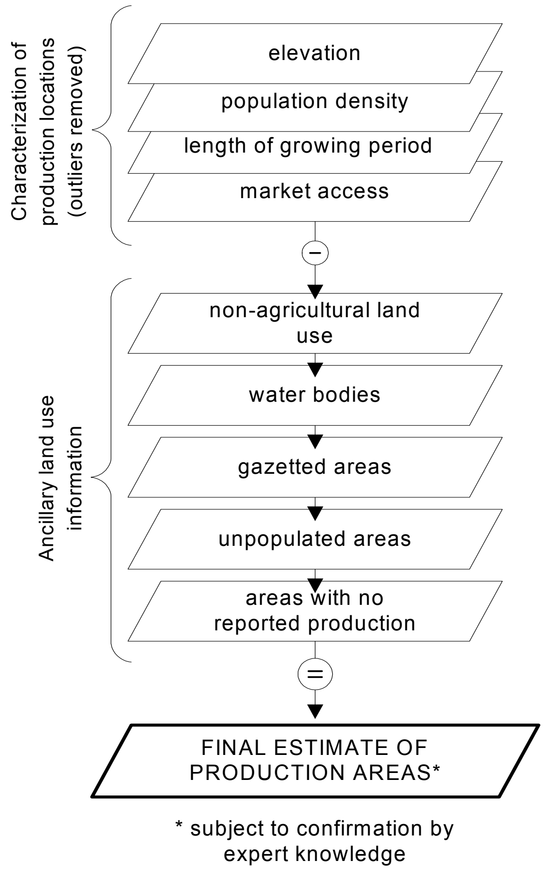
SPATIAL DISTRIBUTION OF COTTON PRODUCTION

In Africa, there is a general dearth of geographically explicit land use data related to different agricultural production systems, especially commodity-specific production. At anywhere above strictly local scales, it is methodologically challenging, as well as very expensive, to obtain geographically precise data on the extent and intensity of agricultural production. Efforts over the past years to harness information from increasingly available remotely-sensed imagery have resulted in enormously improved global estimates of agricultural extent and intensity (Wood *et al*. 2000a, Ramankutty and Foley 1998, Loveland *et al*. 2000, GLC2000 2002), but these estimates are necessarily coarse representations of general agricultural land use and do not directly indicate particular farming systems or the production of specific commodities. Remote sensing holds great promise for delineation of some types of crop specific mapping, especially in industrial/large-scale farming systems, but there is much methodological work still to be done and because of data and processing demands, results are generally constrained to areas of relatively homogenous and well documented land use characteristics.

To overcome this situation we may resort to producing models of likely production areas based upon the best data currently available. These data sources include: production statistics reported for sub-national administrative units, land cover maps derived from remotely sensing and other sources, community and household surveys, and expert knowledge of local agricultural geographies. For the present study, data were available from the Uganda National Household Survey (UNHS) of 1999-2000, land cover data from the Ugandan Biomass Project, estimates of cotton production from CDO-MAAIF (Cotton Development Organization, Ministry of Agriculture, Animal Industry and Fisheries), and expert knowledge of the country's farming system patterns.

The UNHS dataset was the main source of information used in this study. The UNHS includes information for 10696 households in 41 of the 45 circa-1998 districts. 455 of the 8088 farming households in this survey produced a significant amount of cotton. Our initial approaches to mapping cotton production focused on constructing probabilistic statements about cotton production given statistical relationships of cotton-producing households with a range of environmental variables. Because of the relatively low number of households, this approach was not feasible for this study but does hold promise for the spatial delineation of other commodities. Instead, we constructed a cartographic model as follows. The range of environmental, demographic and infrastructure characteristics associated with locations of known cotton production were used to map areas characteristic of current cotton production throughout the country. The resulting mapped area was further modified by removing areas of known non-agricultural land use from the best available land cover data, major water bodies, gazetted lands of the national protected area system, areas with no reported human population, and areas with no reported cotton production, subject to confirmation by sources of expert knowledge. Figure 2.1 graphically describes this cartographic model. Data sources are provided in Appendix I.

Fig 2.1 **– Estimating the location of the cotton production area (CPA)**



Because the sample size and distribution of cotton producing households in the UNHS was very limited (n = 438, with some cotton-producing areas not well- covered by the survey) modeling approaches were very limited. The approach used here is basically a subtractive one: starting with assumed cotton production throughout the area of interest (i.e., all of Uganda), the mapping process is essentially an iterative re-assignation of areas that can be assumed to have little or no production, based on different data sources. The ranges in elevation, population density, length of growing period and market accessibility in which UNHS cotton producing households were found, was used as a first pass in delimiting our estimate of extent of cotton production. The top and bottom 5 percent of sorted values were removed in order to limit outliers, which may have resulted in some cases from data failing to capture very local conditions. The resulting ranges used to define the extent of production in this first stage were: 958 to 2053 meters above sea level (masl); 7-11 month length of growing period (lgp); 19-548 persons per square kilometer; and the equivalent range of the input market accessibility index[3]. Areas that did not meet 3 of these 4 conditions (i.e., had values within these ranges) were assigned as outside the estimated cotton production area. Because of the breadth of these ranges, however, the total area was still very extensive. The subsequent stages involved removing areas from the estimated cotton production area that had no reported production (including estimated district-level production from the CDO-MAAIF), as well as bodies of water, gazetted areas, and non-agricultural lands as estimated by both national (National Biomass Study) and global (Wood *et al*. 2000a) assessments of land cover from remotely-sensed and other sources. The resulting areas were mapped as the "estimated current cotton production area" (referred to subsequently here as the CPA). This map was refereed by Ugandan experts from IFPRI and from the Ugandan Cotton Development Organization (CDO).

The final map of the CPA appears to be reasonable given information constraints. Because it accords well with expert knowledge of the area we are comfortable with its use in this study. Cartographic modeling was done in a raster (i.e., two-dimensional grid) environment, with a resolution of approximately 5 kilometers.

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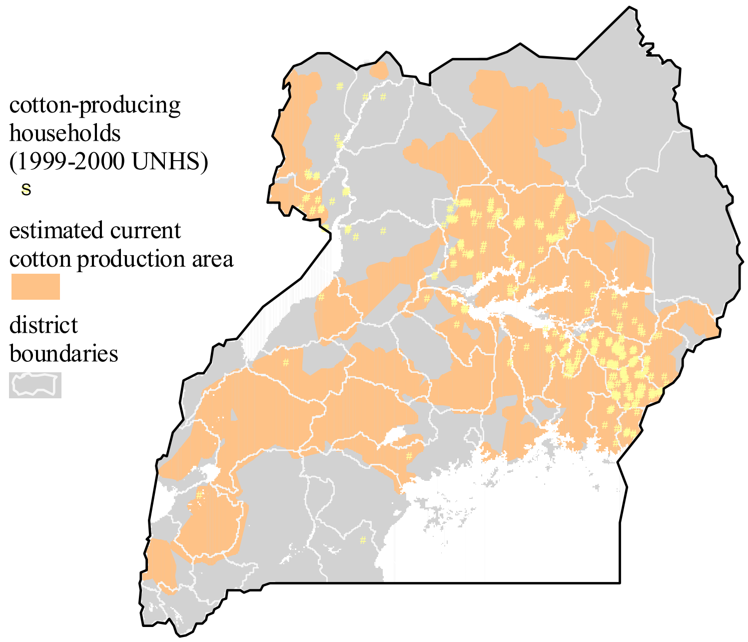
[3] This range is -1.05832823 to 1.738627359 of the standardized index values. This index is based on relative travel time to the nearest three major population centers, weighted by population size.
This variable provides a useful relative measure of accessibility to markets; however, its units are not meaningful in and of themselves, and so actual index values not reported here. The derivation of the index is described in Deichmann 1997.

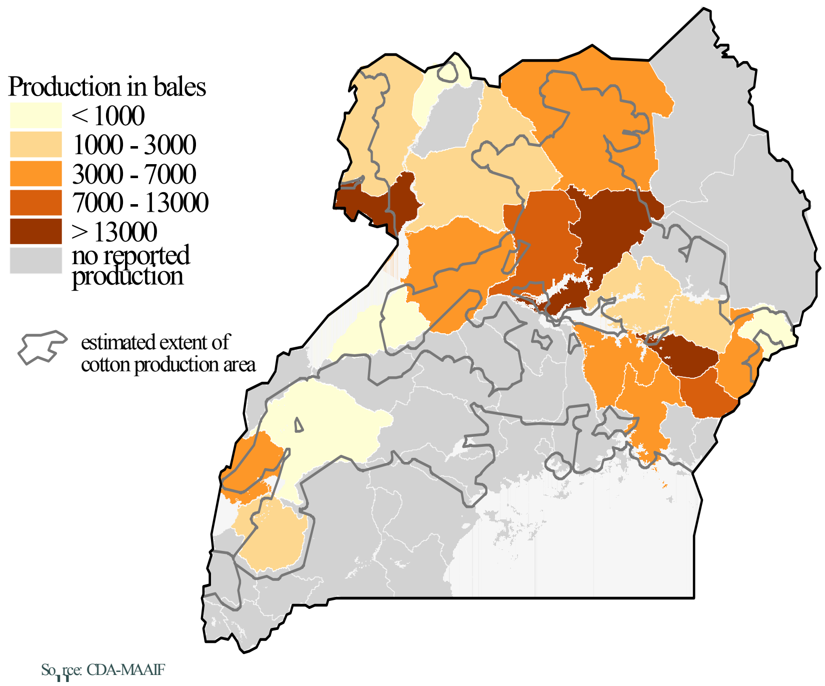
Fig 2.2–Estimated cotton production area (CPA)



Source: Authors' calculations based upon the Uganda National Household Survey 1999-2000.

The map shown in Figure 2.2 conveys the geographically diffuse character of cotton production in Uganda, as indicated by the UNHS data. This diffusion is reflective of cotton's non-perishable nature, widespread favorable climatic conditions and relatively well-distributed processing facilities (see Fig 2.3). Although an important cash generator, as mentioned earlier, data from the UNHS survey do not indicate that it is a mainstay enterprise *per se* in widespread rural livelihoods except in a few isolated areas. The supplemental nature of cotton's contribution to household livelihood strategies may also contribute to the crop's geographically diffuse production patterns.

Figure 2.3--Map of CPA with 1999-2000 district-level production



It is also important to recognize that this formulation of the CPA definition is not truly binary: some areas within the CPA may not have much cotton production; similarly, limited cotton production likely occurs outside the CPA. Nonetheless, the CPA is representative of generalized cotton production patterns and serves as a useful spatial frame for evaluating production reported at the district level, as well as other mapped information, from which we can relate production patterns associated with different enabling and constraining conditions.

SPATIAL DISTRIBUTION AND IMPORTANCE OF COTTON IN RURAL LIVELIHOODS

The estimated CPA is quite extensive and is characterized by a very broad range of biophysical and socioeconomic conditions. Only in the arid and strife-plagued northeast (Kotido, Moroti, Nakapiripiriti) and in the mountainous extreme southwest (Kisoro, Kabale, Ntungamo) is cotton production largely absent at a district-wide level (Mbarara, Rakai, Masaka and Ssembabule also have little or no reported production). Approximately 61 percent percent of the total population lives within the estimated extents of the cotton production areas (more than 14 million people in 2000). Population densities range from very low to extremely high (the average density of the parishes within the CPA is 256 persons per square kilometer). Accessibility to markets and processing facilities similarly varies much within the area, but is generally good, especially in the areas of higher production to the west and south of Lake Kyoga.

Biophysical characterization of the areas is no less varied. Mean elevations in the parishes assigned to the CPA range from 600 masl to over 3000 masl, with a median of 1124 masl. There is cotton production in both areas of unimodal seasonality (i.e., one major rainy period) as well as bimodal seasonality, although most production takes place in bimodal areas. Length of growing period ranges roughly from 7 to 11 months. Using length of growing period as the primary indicator of suitability for rainfed cotton production (FAO 1982), about 11 percent of the CPA corresponds with areas that are "very suitable", 34 percent "suitable", 39 percent "moderately suitable", 8 percent "marginally suitable" and 6 percent "not suitable". The distribution of these areas within the CPA is fairly diffuse, given its rather wide extents.

KEY ECOSYSTEMS AND PROTECTED AREAS

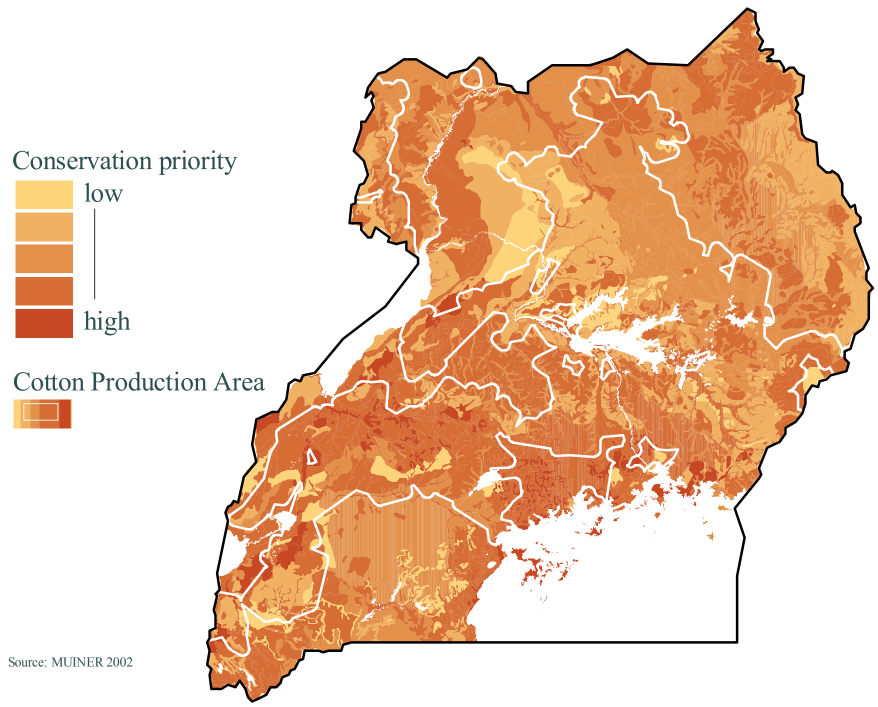
Understanding the relationship between actual and potential cotton production areas and the Uganda's natural resource endowment is essential to understanding potential conflicts between growth within the cotton sector and national conservation priorities. A study by Makerere University, commissioned by IFPRI to inform on-going analytical work in Uganda, evaluated major vegetative landscape types, as proxies for ecosystems, in terms of their conservation importance (Pomeroy *et al*. 2002). This work enables us to identify the location of key ecosystem resources throughout the country (Figure 2.4).

Table 2.1--Major red data species in Uganda

		IUCN Red Data Species (total #)				
BIOME	Langdale-Brown Communities	Flowering plants	Butterflies	Birds	Mammals	Conservation totals
HIGH ALTITUDE	High altitude moorland and heath	0	0	0	0	3
FORESTED	High altitude forests	8	8	8	19	49
	Medium altitude moist evergreen forests	15	17	1	29	68
	Medium altitude moist semi-deciduous forests	17	13	4	22	66
	Forest/savanna mosaics	9	3	0	14	35
MOIST SAVANNAS	Moist thickets	4	1	0	8	18
	Woodlands	1	0	0	0	2
	Moist Acacia savannas	1	0	1	0	3
	Moist Combretum savannas	4	0	1	0	8
	Butyrospermum savannas	4	2	2	2	14
DRYLANDS	Palm savannas	1	2	2	2	8
	Dry Combretum savannas	6	3	3	7	29
	Dry Acacia savannas	1	4	4	13	24
	Grass savannas	4	7	7	15	42
	Tree and shrub steppes	0	3	3	6	13
	Grass steppes	0	2	2	7	12
	Bushlands	1	1	1	6	10
	Dry thickets	1	1	1	2	6
WETLANDS	Communities on sites with impeded drainage	3	2	2	5	17
	Swamps	1	6	6	4	26
	Swamp forests	2	0	0	3	6
POST-CULTIVATION	Post-cultivation communities	2	1	1	4	11

Source: Pomeroy et al. 2002

Figure 2.4--Ecosystem valuation and actual cotton production domain



The Makerere study evaluated available data and methods of ascribing value to the goods and services provided by ecosystems. The alternatives considered are constrained by measurement problems and difficulty establishing a basis for meaningful comparison, a constraint which has been well established in such studies elsewhere. Nonetheless, a weighting of ecosystems by conservation importance was presented, based on known occurrences of IUCN-listed Red Data[4] species of flowering plants, butterflies, birds and mammals (Table 3). Based on this measure, forests, drylands and wetlands were most highly ranked in terms of conservation importance. Uganda's several types of moist savannah were found to have the lowest conservation priority.[5] While imperfect, the resulting mapped

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[4] IUCN Red Data list is the globally-threatening species defined by IUCN, The World Conservation Union (www.iucn.org).
[5] Ecosystems were represented in this work by *vegetation types* defined by Langdale-Brown *et al* (1964) on the basis of plant communities, defined by both floristic and morphological criteria. In terms of specific Langdale-Brown vegetation types, the categories High Altitude Forests, Medium Altitude Moist Evergreen Forests, Medium Altitude Moist Semi-Deciduous Forests, and (dry) Grass Savannahs received the highest conservation

values do present an objectively assigned relative valuation of ecosystems that accords with generally perceived notions of landscape-based conservation priorities. Uganda's forests and wetlands, in particular, have long-standing and well-reasoned arguments advocating their conservation.

The study also noted that the existing system of gazetted areas[6] does a relatively good job of representing important ecosystems. These areas, along with some other areas of formally recognized conservation importance, such as Important Bird Areas, were also ranked according to several criteria. The resulting map of critical conservation sites (Figure 2.5) is a useful additional indicator of areas of potential conflict with expanding agricultural land use. Because the estimate of extent of the actual cotton production domain was in part delimited by the extent of previously mapped agricultural land-use, non-agricultural ecosystems are found outside of the cotton production domain by definition[7]. This is a shortcoming, in the sense that we might be missing some production taking place within protected area boundaries. With more better inputs from land use information from remote sensing and/or more extensive household surveys, future mapping efforts may better capture this. For the time being, we may get some sense of potential encroachment by considering the proximity of cotton producing households to protected areas, as well as the proportion of the CPD falling within a given distance of protected area boundaries. For the 438 cotton producing households in the UNHS, the average distance to the nearest protected area was 14.4 kilometers. 37 percent of those households fell within 10 kilometers and 13 percent fell

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importance. Moist Thickets, Woodlands, Moist Acacia Savannahs, and Moist Combretum Savannas received the least conservation importance.

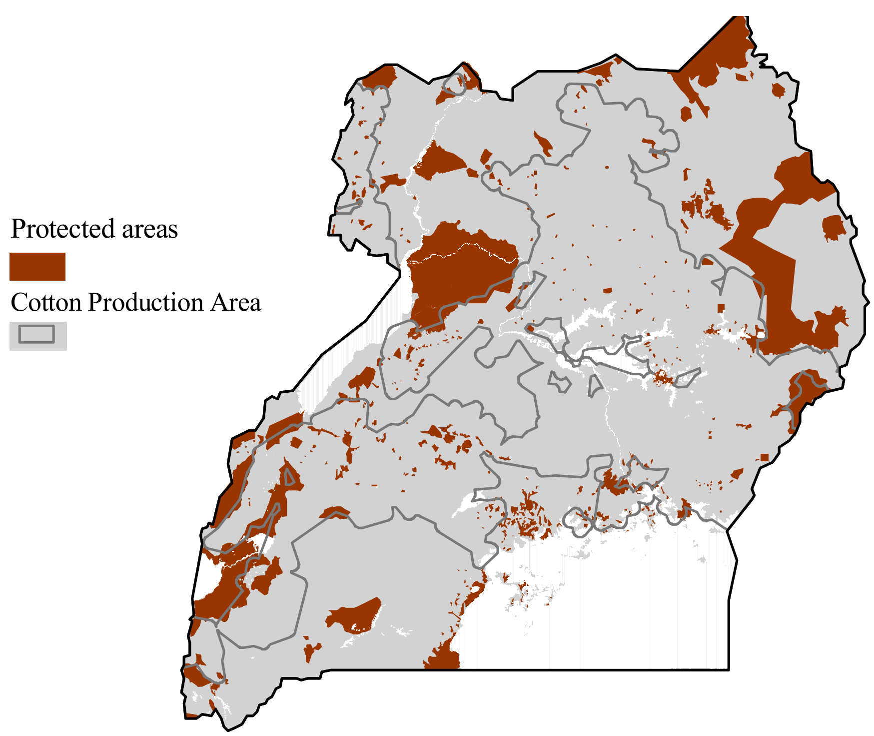
[6] Gazetted areas include National Parks, Wildlife Reserves and Forest Reserves.

[7] Where they are found within the cotton production domain result from one of two reasons: where agricultural land use was defined by the global estimates of Wood *et al*. (2000a) and not by NBS (1996); and areas included after generalization of the boundaries of the cotton production area, in accordance with our definition of these boundaries as essential fuzzy delimitations rather than absolute boundaries

within 5 kilometers. From the perspective of the estimated cotton production area, while admitting that its boundaries are approximate, we may still recognized that almost 60 percent of its area lies within 10 kilometers of the nearest protected area (about a third of its area lies within 5 kilometers).

From a policy perspective, the locations of gazetted areas are important when considering the expansion of agricultural land use. In the case of cotton, which is often employed as a “land opening” crop, the relationship with conversion of forest to agricultural land is, if not notorious, widely recognized. Policy designed to promote expansion of cotton production should consider both the magnitude and location of potential land conversion consequences. We revisit this theme below, when we examine area expansion as a strategy for increasing cotton production.

Figure 2.5--Protected areas and other critical conservation sites



Source: Pomeroy et al. 2002; Lamprey et al. 2003

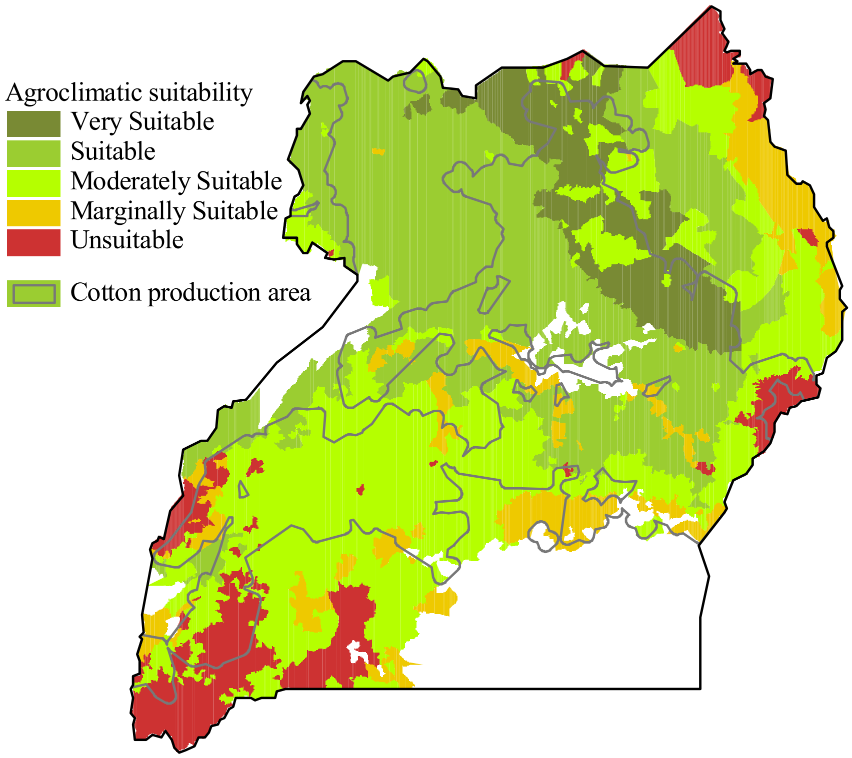
3. COTTON DEVELOPMENT DOMAIN AND LIVELIHOOD ENTERPRISE

Following Bolwig et al.'s (2002) conceptual framework, we define "development intervention space," which we refer to here as Cotton Development Domains. The concept of development domains was first developed by Pender et al. (2001). In an effort to understand the enabling conditions for a range of hypothesized patterns of change in rural livelihood strategies in Uganda, they hypothesized three major factors operating at the community level: agricultural potential, access to markets, and population density. Map layers of these factors were then stratified (e.g., "high" versus "low") and overlaid to produce mapped development domains. We extend this approach by defining domains particular to cotton. These cotton development domains are based on three major factors: existing CPA, agroclimatological suitability, and market accessibility.

AGROCLIMATIC SUITABILITY

No comprehensive and spatially explicit suitability analyses for cotton were available for this study. However, a suitability surface based on relatively length of growing period was modeled on the commodity-specific parameters from FAO's Agro-Ecological Zones Project (FAO 1982). 84 percent of the estimated CPA falls within moderately to very suitable areas. Figure 3.1 shows the boundary of the estimated cotton production areas superimposed on the suitability surface. In terms of districts, Kitgum, Katakwi, Lira and Gulu all have the highest proportions of land in areas most favorable to cotton production by agroclimatic terms. Of these, Katakwi and Lira are also among the highest producing cotton districts.

Figure 3.1–Rainfed cotton suitability and cotton production domain

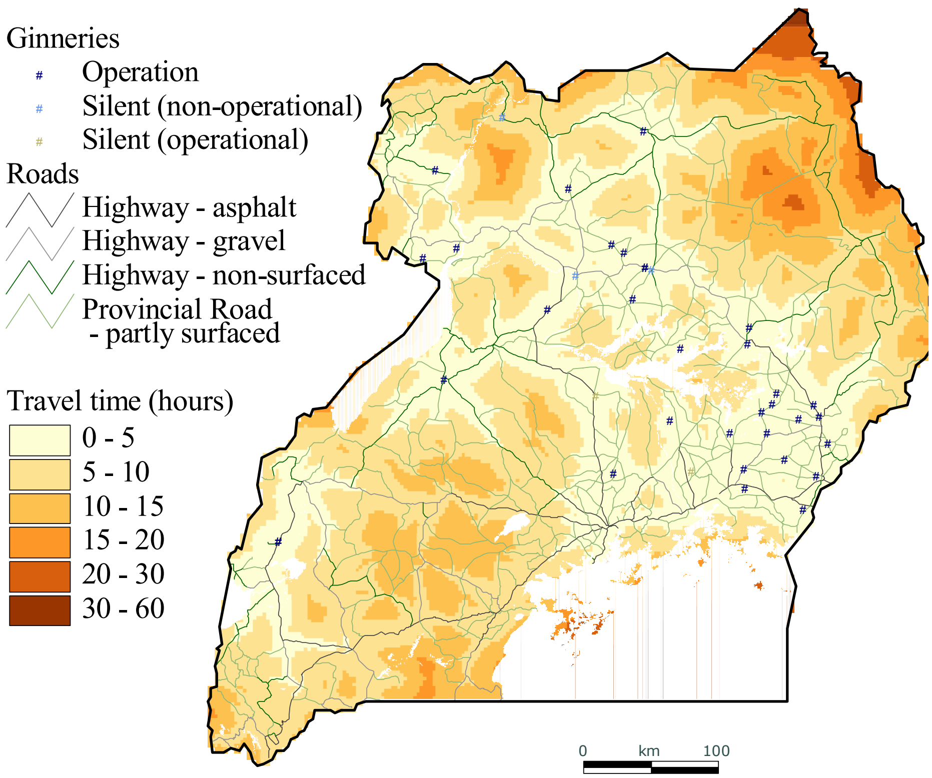


Source: FAO 1982

MARKET AND GINNERY ACCESSIBILITY

For this study, an accessibility analysis was done for operational ginneries (including operational ginneries that are not currently being used to process cotton, but excluding ginneries that are known to be non-operational). This is shown in Figure 3.2. Travel time was estimated as average motor vehicle transit time per kilometer of road type, using average transit speeds. Off-network travel was assumed to be by bicycle or foot and was modeled accordingly. We did not attempt to model seasonal variation in transportation access, although travel times vary considerably by season in many parts of the country (i.e., on un-surfaced roads during the rainy season). It is possible that the road data used (i.e., average travel speeds per section) underestimates travel times in some areas. However, these data and the accessibility maps estimated from them, are felt to be adequate for this study.

Figure 3.2--Accessibility to cotton processing facilities



Source: Authors' calculations based upon ginnery data from CDO and roads data from Ministry of Works, Housing and Commerce and the World Resources Institute

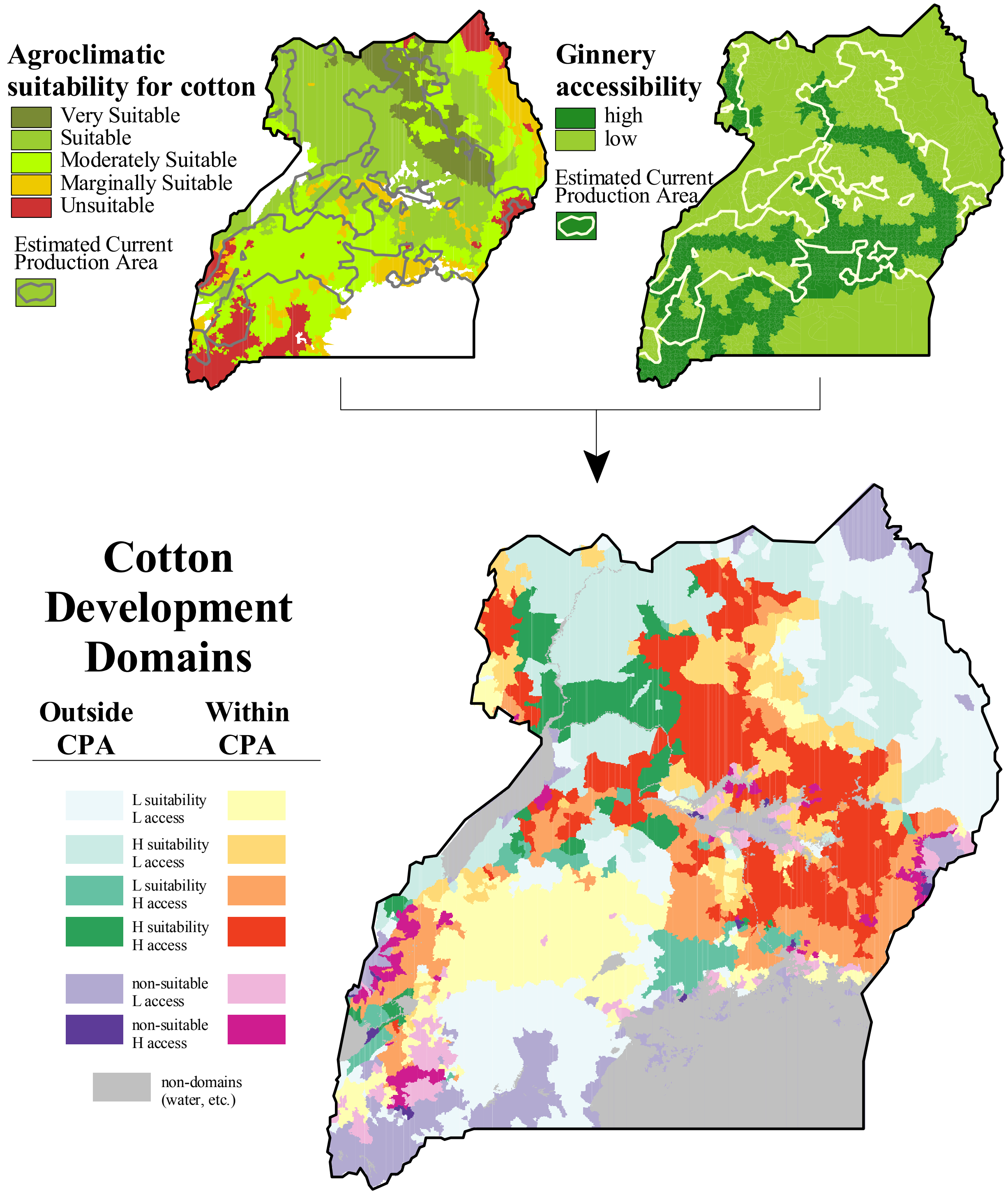
Although cotton production in the UNHS surveyed households occurs across a wide range of market accessibility conditions, the areas of heaviest production are relatively well articulated with the locations of ginneries. No causal relationship is implied here; further study would be needed to evaluate this relationship. Nevertheless, ginnery accessibility does seem to be a good indicator of potential opportunities for cotton producers under current conditions, as they act as a inevitable intermediate step in the delivery of cotton to market.

DEFINITION OF COTTON DEVELOPMENT DOMAINS

Access to ginneries and agro-climatic suitability, together with the estimated extents of the current cotton production areas, may form the basis of decision making domains for cotton development strategies. We have defined 12 such Cotton Development Domains, shown in Figure 3.3. Definition of the domains was done on the basis of parish boundaries, beginning with assignment of these analytical units as within or without the estimated current CPA, followed by parish-level characterization of agroclimatic suitability and ginnery accessibility. Agroclimatic suitability was initially defined for cotton in 5 classes: very suitable, suitable, moderately suitable, marginally suitable and not suitable. Because this surface was based on climate only, and did not include soils information, it captures very broad patterns of suitability. A more detailed study would need to incorporate a consideration of local variation in soil types and properities.

To simplify the resulting domains, we reclassified suitability into three classes: high (very suitable and suitable), low (moderately and marginally suitable) and not suitable. Access to processing facilities was classified as into two categories: high (roughly < 4 hours travel time) and low (> 4 hours travel time). The 12 cotton development domains and their defining criteria are summarized in Table 3.1.

Figure 3.3--Cotton development domains



Source: Authors' calculations based on data from FAO 1982, Ministry of Works, Housing and Commerce and the World Resources Institute

Table 3.1--Production and consumption pattern in Uganda household

Cotton Development Domain	Cotton Production Area (current)	Agro-climatic Suitability	Access to Processing Facilities
1	Outside	High	High
2	Outside	High	Low
3	Outside	Low	High
4	Outside	Low	Low
5	Outside	Not Suitable	High
6	Outside	Not Suitable	Low
7	Within	High	High
8	Within	High	Low
9	Within	Low	High
10	Within	Low	Low
11	Within	Not Suitable	High
12	Within	Not Suitable	Low

COTTON AS A LIVELIHOOD ENTERPRISE

After defining the cotton development domains, it is useful to provide some background on rural livelihood strategies and the role of the cotton livelihood enterprise within these domains. Table 3.2 provides the production and consumption patterns of the 13 major crops in Uganda. The three major staple crops, namely cassava, sweet potato and matooke, together account for 44 percent of total production value and 59 percent of consumption value for the 13 crops. Coffee, as the country's most important export commodity, ranks fourth in terms of production values, and has little domestic consumption. Cotton, the second largest export commodity, represents only 2.2 percent of the total production values for the same 13 crops. No cotton consumption data are reported in the survey because household consumption of cotton is mostly via finished products (e.g., clothes, quilts, cotton lint), for which sales data were unavailable. At the national level, cotton consumption is quite low: only 5-10 percent of national production (CDO 2000).

Table 3.2--Production and consumption pattern in Uganda household

Crops	Percentage of Crop Values	
	Production	Consumption
Cassava	15.26%	16.33%
Sweet Potatoes	14.60%	16.49%
Matooke	14.01%	25.72%
Coffee	12.55%	0.07%
Maize	9.85%	11.82%
Beans	9.33%	12.24%
Groundnuts	8.31%	3.89%
Millet	5.76%	3.99%
Irish Potatoes	4.18%	4.05%
Sorghum	3.08%	1.81%
Cotton	2.20%	
Rice	0.87%	3.59%

Source: Uganda National Household Survey (UNHS) 2000

Although cotton is ranked almost at the bottom of the 13 major commodities in Table 3.2, it is one of the key cash crops for small farmers. The importance of cotton income in rural livelihood varies from one domain to another, even from household to household. So who is growing cotton? Table 3.3 shows the household characteristics of cotton farmers in the 12 cotton development domains defined in the above. Within the CPA, the average household cotton production varies from just over 100 kg (in medium suitability/low access domain) to almost 180 kg (in the high suitability/high access domain). Average cotton plot sizes are small across the board: less than a hectare for all but one domain and for the vast majority of households. The greatest proportion of agricultural households which are cotton producers is in the high suitability/high access domain of the CPA (19 percent). Other domains with substantial proportions of cotton producers are the medium suitability/high access domain within the CPA (6 percent) and the high suitability, non-CPA domains (6-7 percent). The share of the total value of household agricultural production which derives from cotton approaches 6 percent in the high suitability/high access domain; it is much less in all other domains (< 2 percent). Generalizing from these data, we can confirm that cotton farmers are largely producing where conditions are favorable, but that cotton remains a relatively minor component of rural livelihood strategies.

Table 3.3--Household characteristics of cotton growers

Cotton Development Domain									
Estimated cotton production area (CPA)	Agro-climatic suitability	Ginnery accessi-bility	Cotton output per household (*kg*)	Cotton area per household (*ha*)	Cotton yield (*kg/ha*)	Share of households growing cotton (*%*)	Cotton's share of total prod.val. (*%*)	Cotton producing households in sample (*n*)
Cotton	High	High	177	0.75	236.4	19%	5.70%	290
	High	Low	108	0.85	127.9	3%	1.20%	20
	Medium	High	116	0.72	159.7	6%	1.20%	109
	Medium	Low	105	1.04	100.4	1%	0.10%	6
	Low	High	-	-	-	-	-	0
	Low	Low	-	-	-	-	-	0
Non-cotton	High	High	86	0.88	97.8	7%	1.90%	5
	High	Low	153	0.69	221.3	8%	1.20%	4
	Medium	High	136	0.88	155.0	2%	0.40%	3
	Medium	Low	180	0.77	232.7	>1%	0.02%	1
	Low	High	-	-	-	-	-	0
	Low	Low	-	-	-	-	-	0
	average		156	0.76	206.4	6%	1.70%	438

Source: Authors' calculations based upon the Uganda National Household Survey 1999-2000.

It is worth noting that, because of the way that the CPA was defined (i.e., by excluding outlier values in the defining characteristics and with subsequent map boundary generalization), there are some cotton-producing households in the UNHS survey that lie outside the boundaries of the CPA as currently mapped. This is consistent with the definition of the CPA where cotton is most likely, but not exclusively, found. However, because of the small number of cotton producing households in the non-CPA domains, summary statistics for these domains should be viewed cautiously.

To further assist us in interpreting the role of cotton in different domains, we divide the cotton producing households in each domain into income quintiles (Table 3.4). In the two CDDs with high market access, the major cotton production domains, 52% and 32% of cotton producing households are in the top two income quintiles while about 25%, 10% in the bottom two quintiles, respectively. Considering cotton production is concentrated on the two CDDs (one with high suitability and high accessibility, the other with medium suitability and high accessibility), cotton farmers are, overall, the richer smallholders in Uganda. In the two CDDs with low market access, almost three quarters of cotton farmers are in the top two income quintiles. This underlines the importance of cash income from cotton for many households, in particular those in remote areas.

Table 3.4--Proportion of households growing cotton by expenditure category

	Suitability	Market Access	Percentage of cotton producing households in:				
			top quintile	4th quintile	middle quintile	2nd quintile	bottom quintile
Cotton Production Area	**High**	**High**	24.18%	28.41%	20.83%	16.79%	9.80%
	High	**Low**	60.83%	14.06%	14.63%	10.47%	0.00%
	Medium	**High**	14.08%	18.67%	33.92%	23.91%	9.42%
	Medium	**Low**	54.79%	17.40%	15.44%	12.38%	0.00%
	Low	**High**	0%	0%	0%	0%	0%
	Low	**Low**	0%	0%	0%	0%	0%

Source: Authors' calculations based upon the Uganda National Household Survey 1999-2000.

THE COMPETITIVITY OF COTTON AS A LIVELIHOOD ENTERPRISE

The potential explanatory factor for cotton production patterns that may not be adequately captured by the domain variables used here, is that of competitivity with other crops. For example, if cotton is relatively profitable, compared to other potential livelihood enterprises, then it may be produced even in areas that are otherwise defined as low potential. Unfortunately, however, there do not exist spatially explicit data on input costs with which to generate localized competitivity indices derived from net unit returns (i.e., input/output ratios). All nationally-representative information confirms that cotton is less profitable than alternatives, where there are any. For example, a recent study by NAADS (2003) indicated that cotton ranked last of 26 alternative crop enterprises in terms of net profit per unit output (Table 3.5). When cotton's profitability was considered within the subset of commodities grown within the agroecological zones in which it is most prevalent (i.e., the Teso and Banana-Finger Millet-Cotton systems, as defined by NAADS (2003) and elsewhere), its profitability ranking obviously does not change, but it is possible to see that if there are no well-established markets for alternatives to cotton, then cotton may continue to be produced even in areas that would otherwise favor – in terms of yields and relative profitability – the production of other commodities. The lesson here is that more detailed (i.e., spatially disaggregated) information is needed on local input and output markets and other information relevant to profitability, in order to understand the actual and potential patterns of cotton production.

Table 3.5--Comparative profitability of Uganda smallholder crops

	Subsistence/Traditional		High input Technology	
CROP	*Ouput:input ratio*	*Net Profit*	*Ouput:input ratio*	*Net Profit*
Arabica coffee	1.59	222,500	1.87	530,000
Robusta coffee	1.05	23,500	1.52	427,000
Cotton	**0.9**	**-11,400**	**1.46**	**102,700**
Tobacco - flue cured	---	---	1.75	1,028,800
Tobacco - air cured	---	---	1.87	1,004,300
Tobacco - fire cured	---	---	1.45	466,050
Tea (Outgrower)	---	---	1.37	462,000
Tea (Estate)	---	---	1.54	808,750
Cocoa	3.4	310,500	3.69	583,000
Vanilla	5.64	3,887,143	---	---
Papain Latex	1.38	89,000	1.45	262,000
Passion fruit	2.62	464,000	3.49	1,471,000
Hot pepper	---	---	1.34	317,000
Banana	1.41	87,000	2.05	460,000
Maize	0.97	-6,500	1.31	131,500
Finger millet	2.14	346,250	---	---
Sorghum	1.6	174,900	---	---
Wheat	1.32	87,000	1.58	276,500
Upland rice (unhulled)	1.42	164,500	1.89	489,500
Groundnuts (shelled)	1.25	80,750	1.48	261,000
Simsim	1.2	43,450	1.35	125,050
Cassava (fresh)	1.26	103,500	1.56	414,250
Sweet potatoes	1.31	94,750	1.8	426,500
Irish potatoes	1.17	64,000	1.45	389,500

Note: no value ("---") indicates that the crop is not grown under the technology level indicated for the column
Source: NAADS 2003

Cotton production is one of the livelihood enterprises for rural livelihood strategy. Currently, these cotton livelihood enterprises contribute differently to the overall rural livelihood in different cotton development domains. Though the cotton production contributes only modestly to the total household income, we believe cotton to be a critical part of rural livelihood strategies for the following reasons. First, the Ugandan government aims to increase cotton production to reach its historical peak. This promotion is likely to result in an increased importance of the cotton as a rural livelihood enterprise, especially as production expands into new areas. Second, cotton will continue to provide important cash influx to rural household budgets at a critical time of the year. Third, because Ugandan cotton tends to be grown by the poor, improving the viability of cotton as a livelihood enterprise is a sound component of a portfolio of strategies to combat hunger, poverty and malnutrition in Uganda.

4. WELFARE ANALYSIS OF ALTERNATE DEVELOPMENT STRATEGIES

We have defined cotton 12 livelihood domains according to cotton production zones, cotton suitability and ginnery accessibility. To evaluate the impact of different development strategies as outlined in the first section on these cotton–based livelihood enterprises, we use IFPRI's DREAM model (Wood et al. 2000b) to do welfare analysis. DREAM is designed to measure economic returns to commodity-oriented research under a range of market conditions (see Appendix II for details). Table 4.1 shows the base data for DREAM simulation. We estimated the production in each cotton development domain by district-level production weighted by CDD area shares. The domestic consumption of cotton is less than 10 percent of Uganda production, and we put the consumption into one DREAM region (i.e., "national consumption"). The exogenous growth for cotton demand for each region/domain is estimated using the projected growth rate of population as well as the projection of growth in per capita consumption arising from income growth (Alston, Norton and Pardey 1995 p.388). The world cotton production grew at 1.67 percent per year from 1961-2000, -0.26 percent (declining) from 1990-2000, while the corresponding rates for Uganda are –6.1 percent and 11.1 percent. Due to the current 40-year low world cotton price, the world cotton production is declining since 2001 and the cotton price is recovering gradually. For the baseline simulation, we assume the exogenous production growth rate in rest of world is 1.67 percent, the long-term growth rate of world cotton production. This growth rate is little less than the growth for cotton demand. Therefore, the world cotton price will gradually rise during the simulation period (from 2000 to 2020). This imitates the current trend as exhibited by Cotlook A data (USDA 2003). Since cotton market liberalization in 1994, Uganda has enjoyed an impressive production growth rate of almost 10 percent per year. However, this growth came mainly from area expansion, with cotton yields actually declining over the same period. For baseline simulation, we take a production growth rate of 5 percent per year – a modest and achievable rate – for Uganda.

Table 4.1--Base data for DREAM simulation: Cotton lint

Region Groups	Regions	Supply	Demand	Prices	Elasticity Supply	Elasticity Demand	Demand Growth Variables: Income Elasticity	Demand Growth Variables: GDP/capita Growth
		(tons)	(tons)	(US$/ton)				(%/pa)
	CPA, High Suit, High Access	15,350		1,506	1.0			
	CPA, High Suit, Low Access	508		1,506	1.0			
	CPA, Median Suit, High Access	1,863		1,506	1.0			
	CPA, Median Suit, Low Access	146		1,506	1.0			
	CPA, Low suit, High Access	0		1,506	1.0			
	CPA, Low suit, Low Access	0		1,506	1.0			
Uganda	Non-CPA, High Suit, High Access	74		1,506	1.0			
	Non-CPA, High Suit, Low Access	221		1,506	1.0			
	Non-CPA, Median Suit, High Access	113		1,506	1.0			
	Non-CPA, Median Suit, Low Access	16		1,506	1.0			
	Non-CPA, Low suit, High Access	0		1,506	1.0			
	Non-CPA, Low suit, Low Access	0		1,506	1.0			
	Uganda Domestic Consumption		1280	1,506		0.5	0.60	2.55
	Subtotal	18,292	1280					
ROW	Rest of World	19,181,708	19,198,720	1,256	1.0	0.5	0.60	1.36
World	Total	19,200,000	19,200,000					

NOTES

(1) Data are averages for 1999 - 2001 except for t the annual population growth rates and GDP/capita Growth.

(2) Uganda domestic consumption of cotton lint is 5-10% of production. The average World production between 199-2001 is 19.2 million tons.

(3) GDP/cap growth is obtained by substracting GDP growth from World Economic Indicators (World Bank 2000) to population growth rate for 1997;

(4) Uganda FOB price is from CDO (Cotton Development Organization) 2000-01 annual report

ROW price is Cotlook A Index in 2000, which is 57 US cents per pound

The simulation period is 21 years (2000 to 2020), using the year 2000 as a base. These development strategies, either productivity increases or area expansion, start in 2003 and take another 3 years of adoption process to reach the targeted levels. These parameters and others are shown in Table 4.2. As pointed out above, there are three basic strategies for cotton development : (1) area expansion; (2) increasing cotton labor/land productivity; (3) increasing domestic consumption of cotton. In the following, we use DREAM simulations to evaluate the potential impact on cotton export, welfares to Uganda cotton farmers for the three proposed development strategies[8].

[8] It is important to note that DREAM analyses compare different scenarios with a baseline situation, rather than predicting actual changes in future export revenues and producer benefits.

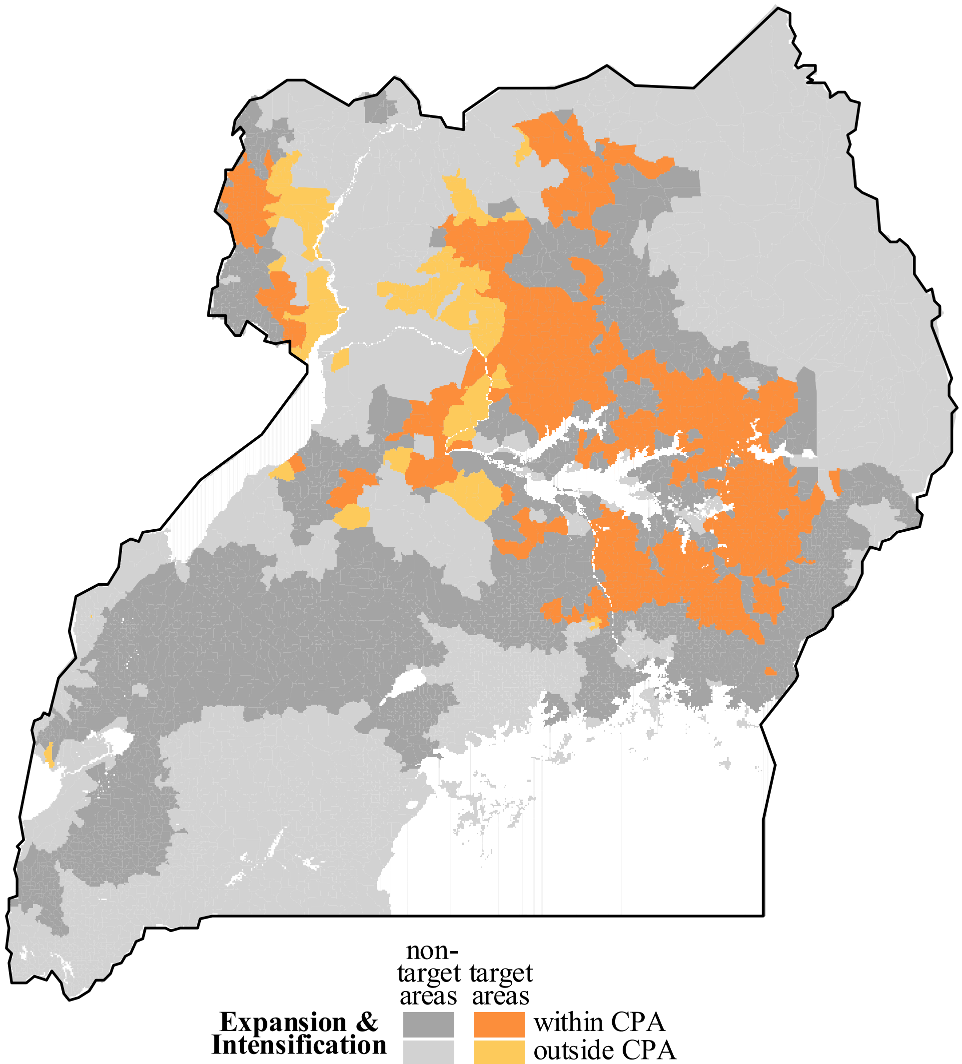
Table 4.2--Baseline scenario conditions and assumptions

Scenario Parameters	Value	Remarks
Scenario Constants		
Base year	2000	1999-2001 average
Simulation period	21 years	2000 to 2020 (21 years)
Real discount rate	3%	used to calculate present values
Market		one market is equivalent to one DREAM region
Initial prices		border prices
Price transmission elasticity	0.8	reflect imperfect transmission of price change effects
Supply		
Initial quantity		1996-98 production averages
Elasticity	1.0	
Exogenous growth		No R&D-induced production growth rate
Tax/Subsidy	0.	
Demand		
Initial quantity		1996-98 consumption averages
Elasticity	0.5	
Exogenous growth		derived from projected population and income growth for each region
Tax/Subsidy	0	
R&D PARAMETERS		
Probability of success	100%	technology will be available for adoption after 3 years
Gestation lag	3 years	
Supply shift		
Supply shifts k	various	Percentage of innovating region's producer price
Adoption profile		
Time to ceiling	3 years	maximum adoption level reached after 5 years
Ceiling level	80%	maximum adoption level
Functional form	Sigmoid	sigmoidal from technology availability to maximum adoption. No disadoption.

AREA EXPANSION

The potential expansion of cotton production can be considered in several ways. For example, the expansion of cotton production can be examined within the current extent of agricultural land use (i.e., expansion of the proportion of total agricultural production that is dedicated to cotton), or we may consider the absolute expansion of agricultural land use (i.e., expansion of cotton into areas not currently under agricultural production). In either view, criteria for evaluating the desirability of cotton production may be identified. In the present study, we identify areas with high ginnery access (closer to existing ginneries) and high cotton suitability, that do not coincide with important protected areas or natural landscape types with high conservation values (as assessed in Section 2). The resulting target areas for expansion are shown in Figure 4.1. This meets what may be considered an optimal set of criteria; a wider set of candidate areas for expansion would be generated by selecting domains matching either (as opposed to both) criteria or, alternatively, by redefining the thresholds for "high" and "low" suitability and ginnery accessibility in the domain definitions. Within the existing cotton production areas, farmers can increase their cotton acreage by opening new land or by switching land used for other crops to plant cotton. Outside the current cotton production areas, there are potential areas suitable for cotton production in North Uganda. A reasonable assumption is that areas of high suitability and access to ginneries present favorable conditions for expansion of cotton production. Based on the data available to this study, CDDs meeting these criteria can be identified, allowing us to map such expansion areas As shown in Figure 4.1, within current cotton production areas, the potential for expansion or intensification locates in northern and eastern Uganda. These include the following districts: Arua, Nebbi, Kitgum, Lira in northern Uganda, Soroti, Katawi, Kumi, Mbale, Pallisa, Tororo, Kamuli, Iganga in eastern Uganda, and small isolated areas with Masindi and Luwero in central Uganda. Outside current production zones, the potential areas for expanding cotton lies in the bordering areas between Gulu and Moyo, Gulu and Nebbi, within Kitgum district in northern Uganda as well as northern parts of Masindi and Luwero in central Uganda.

Figure 4.1--Areas of potential expansion and intensification

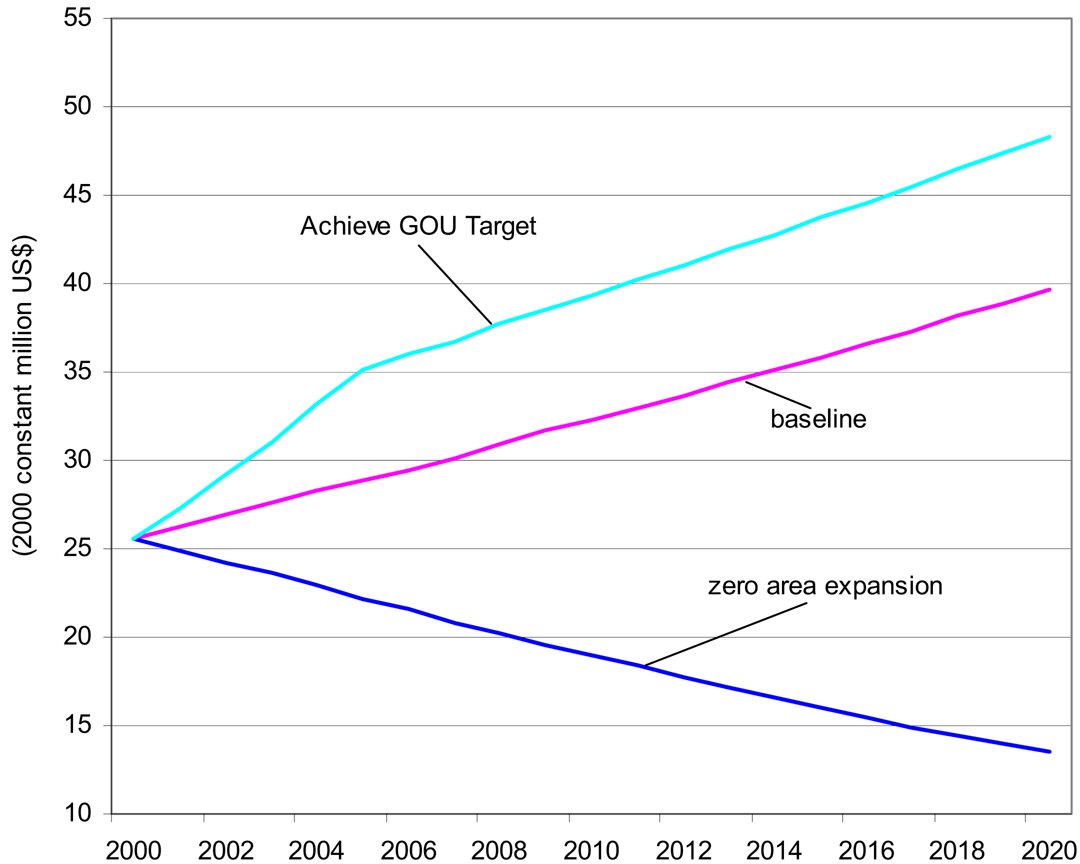


Source: Authors' calculations

We used the DREAM model to estimate how this area expansion affects cotton export revenues. In addition to a baseline scenario, we consider two scenarios of area expansion: (i) Uganda increases neither cotton area not cotton productivity, which means zero production growth rate from 2000 to 2020; (ii) Uganda will increase its production to 300,000 bales (55,500 tons) of cotton lint in 2005 (the target in Government of Uganda (2001) "Government Interventions to Promote Production, Processing and Marketing of

Selected Strategic Exports”). To achieve this production level, we assume 50 percent of production growth would come from area expansion while the rest comes from yield increase. This means an annual area expansion rate of 9 percent per year from 2000 to 2005. After 2005 we assume that production growth will remain at baseline rate of 5 percent per year. Figure 4.2 shows the projection of export revenue from 2000 to 2020 for the three scenarios. For the baseline simulation, the supply growth rate in rest of the world is slightly less than that for demand, which results in a stable world cotton price with a little upward trend. The world cotton price will rise from 57 US cents/lb in 2000 to about 59 US cents/lb in 2020. We think the world cotton price can achieve this modest increase considering the 40-year low price in 2001 and the current price recovery process. This may benefit Uganda cotton production in several ways. For baseline area expansion, Uganda could expect the export revenue of almost $40 million (2000 constant US$) in 2020, which is over 50 percent more than the current export earnings in real terms. The benefit would be even more impressive if Uganda could achieve its target of producing 300,000 bales in 2005. Under this scenario, the export revenue increases dramatically from 2000 to 2005 while Uganda aggressively increases its cotton acreage. After 2005, the export revenue for area expansion alone will be up to $7 million more than the baseline if the 5 percent baseline production growth rate is maintained (Figure 4.2). On the other hand, Uganda could lose up to $26 million potential export revenue in 2020 (i.e., compared to the baseline) if there is no production growth at all (i.e., just maintain the current production level). This scenario implies continuously declining real export revenues due to discounting of the nominal export revenue (Figure 4.2).

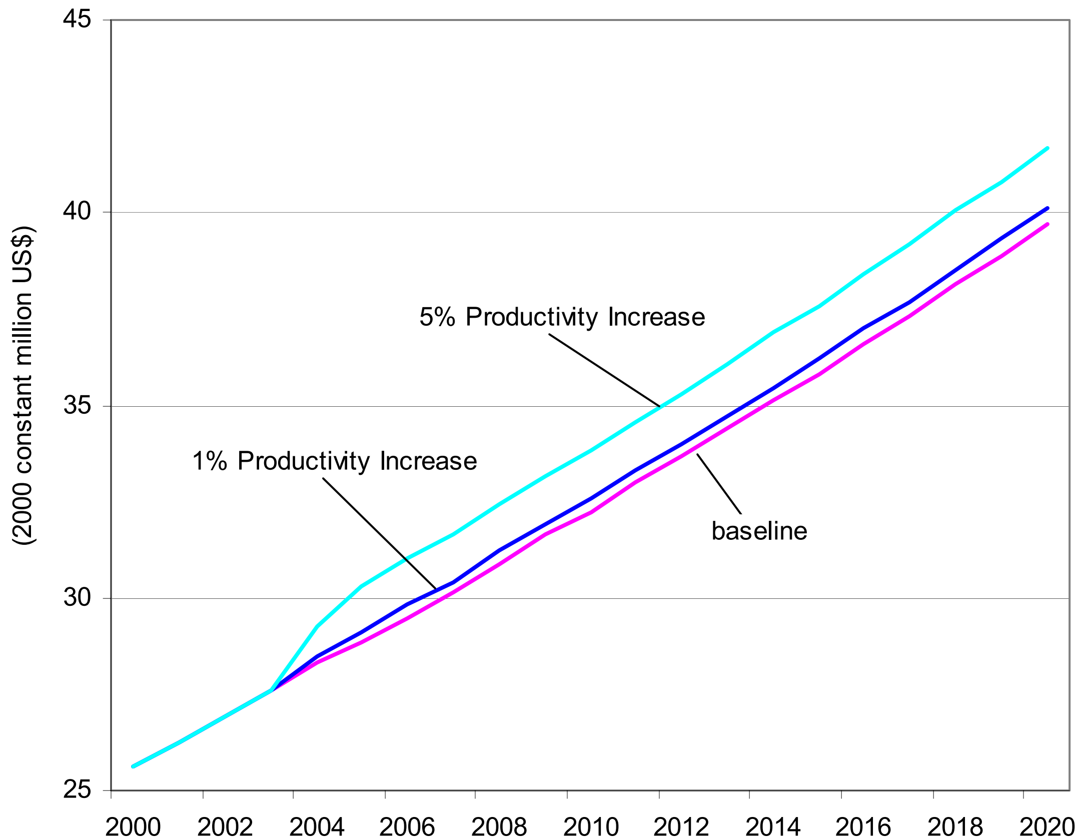
Figure 4.2--Uganda cotton export revenue trend for area expansion



PRODUCTIVITY IMPROVEMENT

Increasing cotton yield or reducing cost of production can both improve cotton productivity. While it is hard to get an accurate estimation of cotton yield in Uganda due to uncertain harvest area (Gordon and Goodland 2000), most data sources estimate the average yield of seed cotton in Uganda to be below 500 kg/ha. This is quite low even comparing to neighboring countries in East Africa, which have an average yield of 900~1100 kg/ha in 1990s (Gibbon 1998). Yields may be increased by addressing the major constraints identified in the former sections. For example, using oxen-driven ploughing rather than hand-hoeing could improve yields by almost 30 percent (Lundbaek 2002). Because disease is a major reason for lower yield in many regions, increased use of pesticides may have large impacts on productivity (AGSEC 1999; AGSEC 1994). Additionally, improved cotton varieties, such as the newly released BPA type, which is resistant to bacterial blight (one of the most serious diseases affecting Ugandan cotton), is high yielding and has better fiber quality, may dramatically improve productivity.

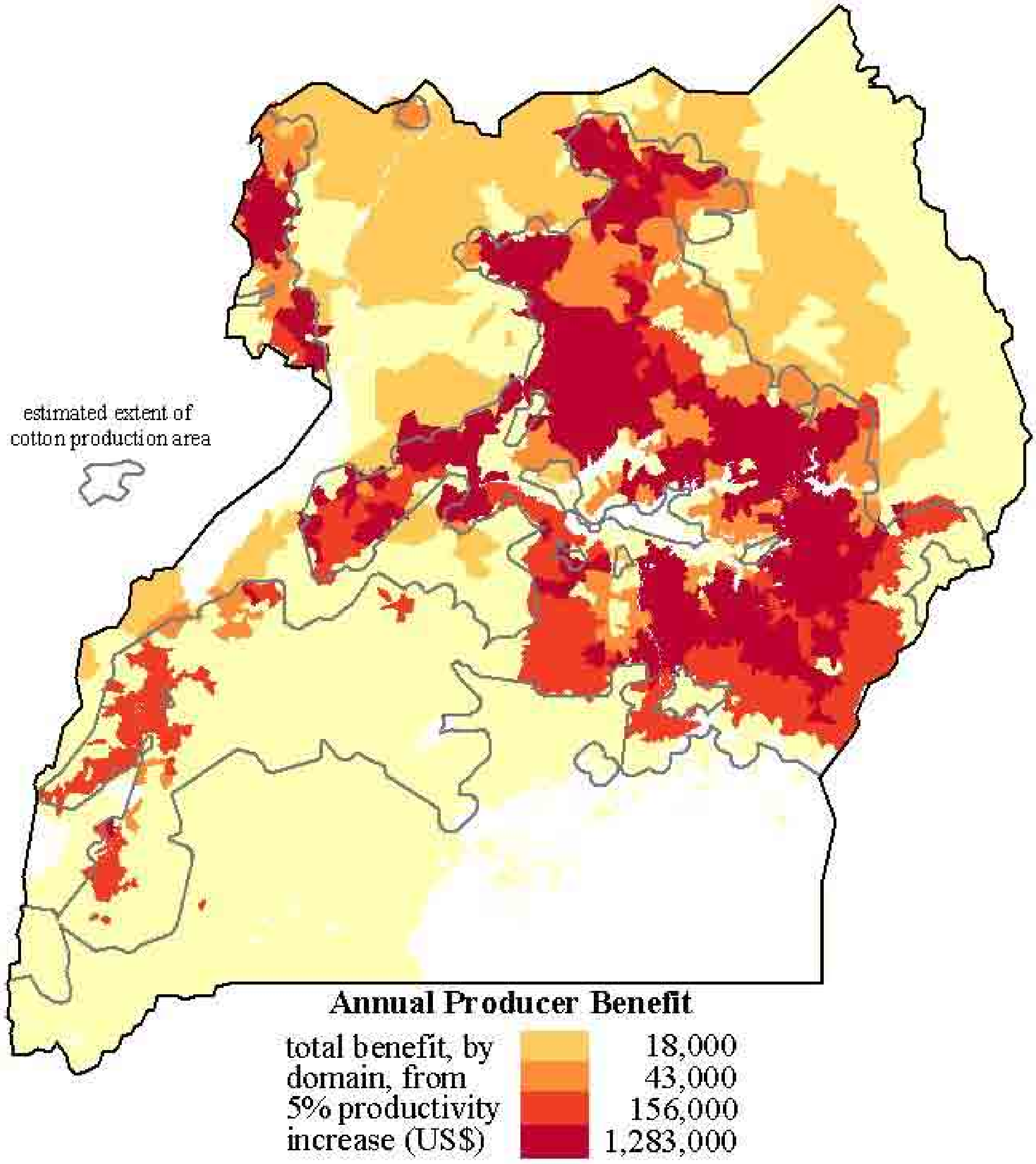
Figure 4.3--Uganda export revenue trend for productivity improvement



In the simulations, we consider two ‘productivity increase’ scenarios for the 2000 – 2020 period: 1 and 5 percent one-time productivity increases in addition to a baseline annual growth rate of 5 percent. Figure 4.3 shows the trends for cotton export revenue. 1 and 5 percent productivity increases result in approximately $0.5 million and $1 million more export earnings per annum than the baseline, respectively. The total (producer and consumer) benefits to Uganda due to these productivity changes are $4.6 million and $23.6 million over the entire period. Figure 4.3 shows the geographical distribution of producer benefits from a 5 percent productivity increase within the estimated current cotton production area (CPA).

The benefits are annual averages of total producer benefits from 2000 to 2020. Within the CPA, areas with high ginnery access and high agroclimatic suitability enjoy the highest producer benefits (almost US$1,300,000 per annum). The areas in this domain are located mainly in northern, northwestern, and southeastern Uganda. The domains with low ginnery access and medium or low agroclimatic suitability gain the least ($0 to $12,000 per annum per domain). These areas are found mainly in central and southwestern Uganda.

Figure 4.4— Benefit distribution from 5 percent cotton productivity increase



The foregoing analyses assessed potential changes in welfare at the national and subnational (domain) scales. Yet it is also important to know how productivity improvements (and other development strategies) are likely to affect production and income at the household level. Table 4.3 shows for an average household in each cotton production domain (CDD) the changes in cotton production, economic benefit, and contribution of cotton to total crop value that can be attributed to 1 and 5 percent productivity increases.[9] With a 1 percent productivity increase, the average cotton producing household could increase cotton production by between 4.9 and 14.5 kilograms per year, depending on which development domain, while the total benefits per household would vary from US$0.6 to $2.1 per year. These changes would increase the contribution of cotton to total crop production by up to 0.5 percent. These effects seem rather insignificant, suggesting that productivity increases would have to be much higher to have a discernible effect on the livelihoods of these households. The 5 percent productivity increase scenario, on the other hand, has a significant impact on household welfare in several domains. The greatest effects on cotton output and economic surplus are realized in CPAs with high agroclimatic suitability and high ginnery access. In this domain, cotton output per household would increase by over 15 kilograms per year and the economic surplus around US$11 per year. The contribution from cotton production to household income also increases by almost a quarter percent. For the other domains with cotton production, the output increases by 5 to 7 kilograms per year while the benefits to household are $3 to $5 per year.

Table 4.3--Household benefit due to productivity improvement

			Cotton development domain (within current CPA)					
	Agroclimatic suitability		High	High	Med	Med	Low	Low
	Market access		High	Low	High	Low	High	Low
1% productivity increase	Change in cotton output per household	*kg/year*	14.54	6.50	4.87	5.06	0.00	0.00
	Benefits per household	*US$/year*	2.14	1.05	0.72	0.64	0.00	0.00
	Change in cotton's share of total production value	*%*	0.05	0.01	0.00	0.04	0.00	0.00
5% productivity increase	Change in cotton output per household	*kg/year*	15.26	7.31	5.18	5.90	0.00	0.00
	Benefits per household	*US$/year*	10.86	5.34	3.65	3.26	0.00	0.00

[9] The economic surplus per household was calculated simply by dividing the total producer benefits in each CDD by the number of cotton growing households. The change in contribution of cotton production to total crop value was calculated using this economic surplus and the total value of crop production in the domain. These are simple methods that do not consider the heterogeneity of households within each CDD.

Change in cotton's share of total production value	%	0.24	0.06	0.02	0.20	0.00	0.00

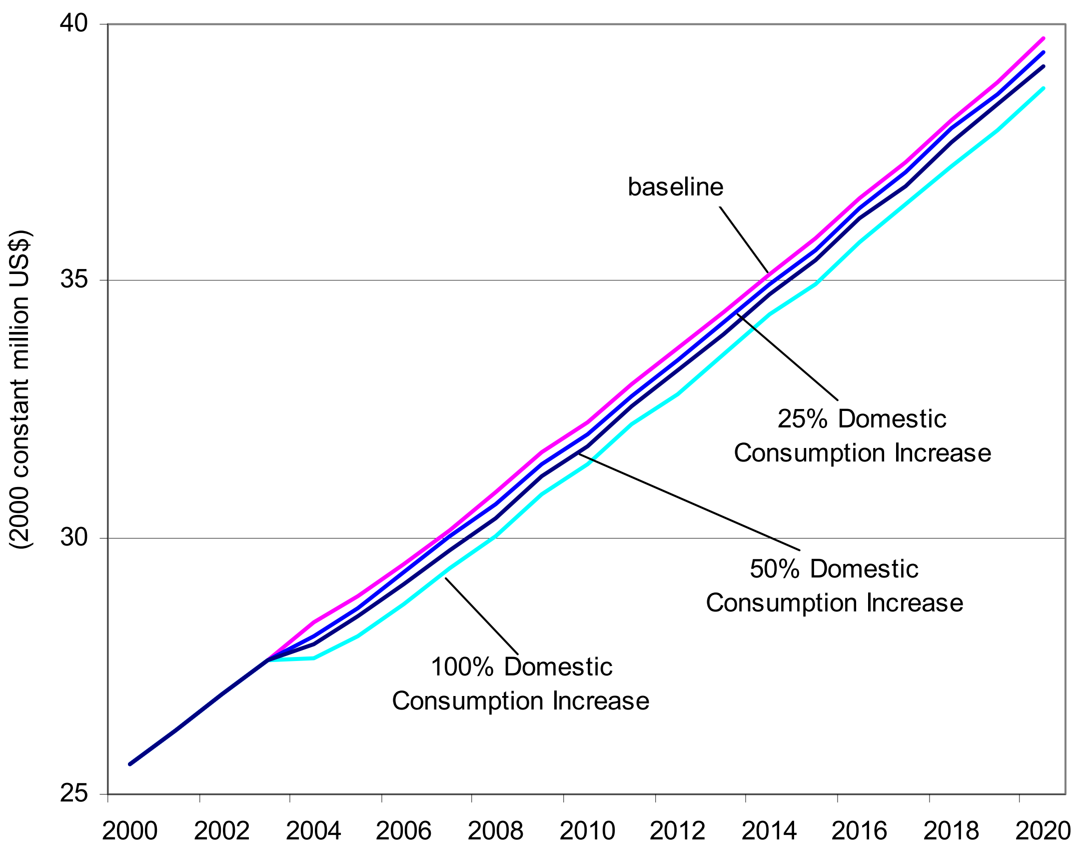
Notes: The table refers to cotton development domains situated within the estimated current cotton production area (CPA).

INCREASED DOMESTIC CONSUMPTION

Uganda's current domestic consumption is less than 10 percent of total production, and there is little capacity to manufacture garments at international standards. By promoting development of the garment manufacturing sector, more cotton production would be consumed domestically and the benefits of added value would likely have important domestic impacts. As mentioned above, AGOA provides a good opportunity for strengthening development of this sector. However, even with such advantageous terms of trade, Uganda textiles would have to conform to quality standards, competitive prices and timing of delivery. For DREAM simulations, we assume three scenarios of increasing cotton consumption: 25 percent, 50 percent and 100 percent over the current consumption level of about 1,280 tons. Such increases would result in 300, 600, and 1100 tons additional domestic consumption after full adoption in 6 years, respectively. Considering the currently low levels of domestic consumption, we think these are all achievable objectives. Figure 4.5 shows the export revenue trend of these scenarios. Note that compared to the baseline, increasing domestic cotton consumption reduces export revenues because less cotton is exported. The export losses per year relative to the baseline are modest, about $0.15 million, $0.45 million, $0.90 million respectively for 25 percent, 50 percent and 100 percent increases in domestic consumption. On the other hand, cotton consumers in Uganda gain huge benefits by selling or exporting value-added clothing and apparels. Cotton producers gain moderately because of the increased (even very small) domestic cotton price. The total benefits (NPV values in 2000 constant US$) over the period 2000 to 2020 are $7.6 million, $15.96 million, $34.7

million for the above three scenarios, which corresponds to annual values of $0.5 million, $1.04 million, $2.25 millionrespectively. . These gains are far bigger than the losses from export earnings.

Figure 4.5--Uganda export revenue trend for increasing domestic consumption



In the preceding sections, we have described the three intervention strategies for cotton development and investigated what these interventions means for Uganda as a whole and for Uganda households in terms their livelihood enterprises. Table 4.4 compares the three strategies in terms of total export revenue and social benefits. If Uganda doesn't increase its cotton production at all through 2020, cumulative losses in potential export revenue are estimated at $26 million by 2020. On the other hand, the Government of Uganda's goal of producing 300,000 bales of cotton annually would result in approximately $7 million of additional export revenues - even though only half of it comes from area expansion. Increasing domestic consumption would lose some export revenue but the social benefit gains are twice as much. The most promising development strategy, maybe not surprising, is productivity improvement. Uganda would gain more export revenue and large social benefits by increasing its currently low productivity in cotton production. A simple 1 percent one-time productivity improvement would mean half a million more export earnings per year and $0.3 million additional social benefits.

Table 4.4—Summary of cotton development scenarios

Development Strategy	Development Scenarios	Change Relative to Baseline: Export Revenue (million US$/year)	Change Relative to Baseline: Social Benefit (million US$/year)
	5% Growth Rate (Baseline)		
Area Expansion/contraction	Zero Growth Rate	-26.0 ~ 0	-1.47
	Government of Uganda Export Plan	7.00	1.72
	25% Increase	-0.15	0.50
Increase Consumption	50% Increase	-0.45	1.04
	100% Increase	-0.90	2.25
Productivity Improvement	1% more than Rest of World	0.50	0.30
	5% more than Rest of World	1.00	1.53

Note: All the values are approximate due to technology adoption process and changing market situations form year to year

5. CONCLUSION

This report applied the spatially-based strategic planning framework for rural livelihood and land use to cotton production in Uganda. First we provide a general historical review of cotton production in Uganda. We then described the farm-level constraints and the major challenges and opportunities in Uganda cotton production. Cartographic modeling is applied to obtain a spatial distribution of cotton production based on 2000 Uganda national household survey. This mapping takes account of various factors including biophysical and agroclimatic characteristics such as elevation and length of growing period, as well as population density, district cotton production statistics and expert knowledge of regional production patterns. Cotton development domains (CDDs) are defined by the following three parameters: cotton production area (in/out), agroclimatic suitability, and ginnery access. We used household survey data to evaluate the importance of cotton as a livelihood enterprise and its role in rural livelihood strategies. Ecosystems with key biodiversity resources and protected areas are also considered in conjunction with the CDDs to identify areas with potential for agricultural expansion. Finally, the DREAM model is used to investigate three development strategies for each of the CDDs: area expansion, productivity improvement and domestic consumption increase. The impacts of these interventions on the cotton livelihood enterprise areconsidered.

Despite rapid production expansion, current cotton production in Uganda is still less than one-quarter of its historical peak. The production growth has stagnated in recent years. Many factors contribute to this stagnation. Farm-level constraints include low productivity, insufficient research and training, inadequate availability of input supplies, limited access to credit for small farmers, low profitability due to low cotton price. Other factors include inadequate information support, inadequate government support, underutilization and technologically aging ginneries. However, Uganda has a comparative advantage in producing cotton, both in terms of favorable agroecological conditions and the stable (even growing) world market for its cotton with high-grade fiber of medium staple length. In addition, the recovering world cotton price and the AGOA provide excellent opportunities for Uganda to boost its cotton production. Under all these favorable conditions, we think Uganda could achieve its goal of producing 300,000 bales of lint cotton by 2005. The three development strategies studied here need to be promoted simultaneously to achieve the production target. By improving productivity, which is very low for the region, Ugandan cotton farmers can increase the profitability of cotton. This is likely to encourage the expansion of more land into cotton production, and the entry of new producers. The current analysis provide potential cotton expansion area without compromising conservation. By taking advantage of AGOA, increasing domestic consumption would add value to raw cotton and results in huge social benefits to Uganda though the revenue of exporting raw cotton declines. For example, Uganda could achieve the Ugandan government's target of 300,000 bales of cotton in 2005 by expanding its cotton area by 9 percent per annum and improving the current cotton yield by around 10 percent.

Nationally, cotton production plays a relatively small part in rural livelihoods in terms its contribution to household income, although its importance varies from place to place. For example, a significant amount of farmers in the northern and eastern regions (the major cotton production zones in Uganda) depend on cotton for nearly one-fifth of their total household income. Cotton's importance to rural livelihood strategy is also reflected in the fact that selling cotton, together with coffee for some farmers, provides the only cash for most small holders in rural Uganda. In addition, the cash from selling cotton comes in convenient time when there are many cash expenditures such as Christmas gifts, taxes, and school fees. The cotton development strategies will no doubt affect the attractiveness of cotton as a household livelihood enterprise. Area expansion would move cotton upward in the ranking of commodities contributing to the rural livelihood because of larger production.

Improved productivity means more income from cotton production and higher contribution to rural livelihood from cotton production. For example, a 5 percent productivity increase could increase the contribution of cotton livelihood enterprise to rural livelihood by 0.03 to 2.2 percent, depending on the particular cotton development domain. Increasing cotton consumption by enlarging textile industry allows Uganda to capture the value added to raw cotton. This is good for cotton livelihood enterprise in two ways. Directly, increased domestic demand for cotton means higher prices and demand for cotton, and reduced transaction cost for cotton farmers. Indirectly, the cotton farmers will also benefit from more off-farm opportunities deriving from development of local textile industries.

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APPENDICES

Appendix 1--Sources of spatial data used in this study.

locations and characteristics of smallholder households	1999-2000 Uganda National Household Survey, Crop and Socioeconomic Questionnaires. Uganda Bureau of Statistics. Entebbe, Uganda.
potential market integration index	unpublished data from World Resources Institute
Ugandan road network data	unpublished data from World Resources Institute
elevation	USGS (1998), *GTOPO30: Global 30 Arc Second Elevation Data Set*, United States Geological Survey's Earth Resources Observation Systems (EROS) Data Center,. Sioux Falls, SD: USGS EDC.
population density	IFPRI calculation from 1991 National Census data, from Uganda Bureau of Statistics. Entebbe, Uganda.
location of ginneries	IFPRI data collection
critical areas	MUIENR report (2002), based on Langdale-Brown data
landscape types and conservation values	MUIENR report (2002), based in part on Langdale-Brown vegation data
administrative boundaries	Gerd Ruecker
agricultural land use	(1) Wood, S., K. Sebastian, and S.J. Scherr (2000), Pilot Analysis of Global Ecosystems: Agroecosystems, Washington, DC: International Food Policy Research Institute and World Resources Institute. (2) National Biomass Study, 1:50,000 land use map for Uganda.
agroclimatic potential for cotton	IFPRI calculation, based on: FAO (1981), "Report of the

	Agro-Ecological Zones Project", World Soil Resources Report No. 48, vol. 1-4, Rome: Food and Agriculture Organization of the United Nations (FAO).
climatological data	(1) Hutchinson, M. F., H. A. Nix, J. P. McMahon, and K. D. Ord. 2001. "The development of a topographic and climate data base for Africa", available on-line at http://www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/sf_papers/hutchinson_michael_africa/africa.html (2) Datasets from International Institute for Applied Systems Analysis (IIASA) associated with: FAO/IIASA (2000), Global Agro-ecological Zoning, FAO Land and Water Digital Media Series No. 11 (CD-ROM), Rome: Food and Agriculture Organization of the United Nations, and Laxenburg, Austria: International Institute for Applied Systems Analysis.

Appendix II--The DREAM model

DREAM stands for Dynamic Research EvAluation for Management (Wood, You and Baitx, 2000). DREAM is designed to measure economic returns to commodity-oriented research under a range of market conditions, allowing price and technology spillover effects among regions as a consequence of the adoption of productivity-enhancing technologies or practices in an innovating region. Linear equations are used to represent supply and demand in each region with market clearing enforced by a set of quantity identities and price identities. It is a single-commodity model without explicit representation of cross-commodity substitution effects in production and consumption --- although, of course, these aspects are represented implicitly by the elasticities of supply and demand for the commodity being modeled. In particular, DREAM assumes all commodities are tradable between regions (although a spectrum of possibilities from free trade to autarky can be represented). The supply, demand and market equilibrium are defined in terms of border prices which will differ from prices received by farmers (or paid by consumers) because of costs of transportation, transactions, product transformation, and so on that are incurred within regions between the farm and border. The linearity of DREAM model is good for small equilibrium displacements such as those single-digit percentage shifts of supply or demand, which is common for most of agricultural technology changes. Alston and Wohlgenant (1990) showed that changes in benefits estimates from comparatively small equilibrium displacements of linear models provides a reasonable approximation of the same shifts (in this case parallel shifts) with various other function forms. Small shifts have the added virtue that the cross-commodity and general equilibrium effects are likely to be small (and effectively represented within the partial equilibrium model), and that the total research benefits will not depend significantly on the particular elasticity values used (although the distribution of those benefits between producers and consumers will). Even with all these simplifications, which make the DREAM model tractable, significant effort is needed to parameterize and use the model to simulate market outcomes under various scenarios (Alston et al 1995; Alston et al. 2000).

The primary parameterization of the model's supply and demand equations is based upon a set of demand and supply quantities, prices, elasticities in a defined "base" period. DREAM also allows for underlying growth of supply and demand to be built into the model to project a stream of shifting supply and demand curves into the future that we can solve for a stream of equilibrium prices and quantities, in the "without research" scenario. These "without research" outcomes can be compared with "with research" outcomes, which are obtained by simulating a stream of displaced supply curves, incorporating research-induced supply shifts. The research-induced supply shifts are defined by combining an assumption about a maximum percentage research-induced supply shift under 100 percent adoption of the technology in the base year, with an adoption profile, representing the pattern of adoption of the technology over time. Finally, measures of producer and consumer surplus are computed and compared between the "with research" and "without research" scenarios, and these are discounted back to the base year to compute the present values of benefits. In the case that we know the costs of the research that are responsible for the supply shift being modeled, DREAM will compute a net present value or internal rate of return (IRR).

DREAM has been developed into a computer software package (Wood, You and Baitx, . 2000). It has menu-driven, user-friendly interface which hides the complex computation to allow user to focus on methodology, data collection and policy interpretation.

DREAM explicitly includes four market types: horizontal multi-market, open economy, closed economy, and three-level vertical market. The region in DREAM can be any spatial unit, either geopolitical region such as country, province, county or agroecological zones such as humid and temperate zone, tropics and arid zone. DREAM allows users to specify technology shifts, adoption, elasticities, and exogenous growth rates that change over the simulation period. It provides a framework for exploring various kinds of policy, technology, extension and trade issues (Alston et al. 2000).

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